A NEW SPECIES OF SAUROPOD DINOSAUR, *HAPLOCANTHOSAURUS DELFSI* SP. NOV., FROM THE UPPER JURASSIC MORRISON FM. OF COLORADO

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Abstract

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Abstract

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Introduction

In 1901 the newly appointed curator of vertebrate paleontology at the Carnegie Museum in Pittsburgh, John Bell Hatcher, decided to reopen the Marsh-Felch quarry in Garden Park, Colorado, about ten miles north of Cañon City. This quarry had produced the type specimens of a number of species of dinosaurs including *Diplodocus longus, Allosaurus fragilis, Ceratosaurus nasicornis, Stegosaurus stenops, and "Morosaurus" agilis.* W. B. Utterback was sent to the field and during the summer's operations, collected two medium-sized, partial skeletons of a new genus of sauropod dinosaur. The more complete of these, CM 572, was subsequently described in a brief paper by Hatcher (1903a) as *Haplocanthus priscus.* Four months later he altered the name to *Haplocanthosaurus* (1903b:100) because *Haplocanthus* was "essentially preoccupied" by a genus of fish named by Agassiz (1844). In November 1903, Hatcher published a monograph on *Haplocanthosaurus* in which the second skeleton was also described as a new species, *H. utterbacki* (CM 879). Since the publication of Hatcher's memoir, very little has been added to our knowledge of this animal. In a review of the sauropods, von Huene (1929) modified several of Hatcher's conclusions and suggested that the number of dorsal vertebrae should be reduced from 14 to 12. In a paper redescribing *"Morosaurus" agilis* Marsh, 1889, Gilmore (1907) conjectured that its type specimen, a cranial fragment and cervicals 1 to 3, might belong to *Haplocanthosaurus,* and this remains a distinct possibility as discussed below. Finally, in 1981, McIntosh referred some limb bones from the type locality to this form as probable.

No new material belonging to this genus was reported until summer of 1954, when a field party from the Cleveland Museum of Natural History began excavating a large sauropod skeleton on the east bank of Oil Creek (Four Mile Creek, Nine Mile Creek) less than a mile south of the historic Marsh-Felch Quarry 1 (Fig.1).

History of the CMNH Quarry (The "Sawropod Lode")

Early in the summer of 1954, William E. Scheele, then director of the CMNH, dispatched a small field party to several western states with the expressed aim of finding a mountable dinosaur for exhibit. The search initially centered around Vernal, Utah, where the crew was "shown the
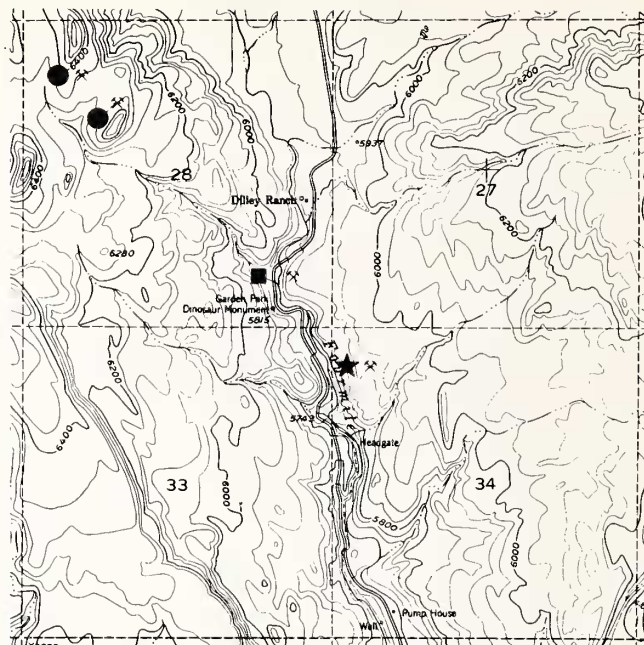

Fig. 1. Map showing location of the CMNH *Haplocanthosaurus* Quarry (★), and the nearby Marsh-Felch (■) and the Cope-Lucas Quarries (●). Cooper Mtr. Quadrangle, Colorado.

ropes'' by Leroy "Pop" Kay, long-time curator at the Carnegie Museum. Kay also provided leads to several promising sites. Although several specimens were located, none proved workable due to problems of obtaining permission or the difficulty of the required excavation.

The field party then split in two, one group headed by director Scheele travelling northward into Wyoming and the second moving eastward into Colorado. While camped at the Colorado National Monument near Grand Junction, a member of the Cleveland crew overheard a conversation between students in a geological field party who had found and collected a partial bone in a stream exposure near Cañon City. Dr. Carl Sanderson, a geologist at Louisiana State University and leader of that University's summer field camp, kindly provided a map of the site. The bone fragmnent was given to the CMNH crew, and later proved to be the posterior end of the fourth cervical vertebra.

The first day's excavation demonstrated the presence of a considerable amount of bone, and it soon became apparent that the major portion of a skeleton was present. The quarry site (Figs. 1, 2A) is located just off the road, on the east bank of Four Mile Creek in the NW 1/4, NW 1/4, Sec. 34, T.17S, R.70W, Fremont County, Colorado (Cooper Mt. Quad.). Since this was during a major uranium boom, it was deemed necessary to protect the site from potential prospecting damage by filing a claim with the Fremont County recorder. A letter from the County Clerk and Recorder's office, dated October 21, 1954, states "The name of this lode is Sawropod, and the reception number is 289758."

Fig. 2A   The CMNH Quarry from the road leading north from Cañon City. Early summer, 1954.

The bones were recovered from the lower part of the Morrison Formation, in a light gray clay layer, bound both above and below by massive sandstone ledges (Figs. 2B, 2C, 3). The upper sand was five- to eight-feet thick and was overlain by some eight feet of sand and gravel. Quarrying operations during the first field season consisted of tunneling under the overlying sandstone which was shored up with vertical timbers. By the end of the season, the practical limits of this technique had been reached and the remaining excavation, in 1955 and 1957, (Fig. 4) was accomplished by removing the overburden with a bulldozer and blasting away the sandstone ledge.

Each of the three years' excavations was led by Edwin Delfs, then an undergraduate biology major at Yale University. Other field crew members were high school and college students Wesley Williams, William West, and Richard Jones (1954), Wesley Williams and Joseph Hurley (1955), and Ralph Wrisley (1957). A local rancher, Joe Rhode, of Garden Park, Cañon City, did the bulldozer work

and provided invaluable advice on construction matters and in handling the large and often very heavy blocks. Members of the "permanent" field crew were supplemented from time to time by a number of Cleveland Museum staff members and volunteers, most notably Mary Flahive, Elizabeth Olmstead, David Roberts, William Scheele, Dan Snow, and Ellen Walters.

The skeleton was lying on its left side and was largely articulated. As so often happens with sauropod skeletons, the neck was drawn sharply backward and the skull had snapped off and was not found. The anterior dorsal vertebrae and all but the first four cervicals had been eroded away by the stream. The posterior two-thirds of the tail was also missing. The ribs and girdle bones of the under (left) side were in place, but only the ilium remains of the right side. The only limb bones preserved were the left femur and the heads of two bones restored as the left tibia and fibula. Other vertebrate remains found with the skeleton include a number of turtle fragments, an isolated theropod tooth, and

Fig. 2B.   Installing timbers, early summer, 1954. Left to right, Wesley Williams, Richard Jones, William West.

the skull and partial skeleton of a new goniopholid croco-dile, *Eutretauranosuchus delfsi* (Mook 1967).

The members of the field party are to be congratulated for their skill in exhuming the huge but often very fragile bones, particularly the vertebrae. Some of the packages were opened in the winter of 1954-55 (Delfs 1961) and the skeleton was determined to be *Haplocanthosaurus*. Further preparation and restoration of the missing parts prior to mounting the skeleton were accomplished at the American Museum of Natural History in New York under the super-vision of veteran preparator George Whitaker. The speci-men was first displayed in Kirtland Hall at the Cleveland Museum of Natural History in 1961, with the body resting on the ground. It was remounted in the upright pose shown in Figure 5 two years later. Although brief notices have appeared in the popular press (Anonymous 1959; Delfs 1961; Pearl 1975; Piel 1963; Anonymous 1966; Williams 1982), the skeleton has not been described.

Abbreviations

AMNH	American Museum of Natural History
CM	Carnegie Museum of Natural History
CMNH	Cleveland Museum of Natural History
OUM	Oxford University Museum
USNM	National Museum of Natural History
YPM	Yale Peabody Museum

Systematic Paleontology

Class Reptilia
Subclass Archosauria
Order Saurischia Seeley
Suborder Sauropoda Marsh
Family Cetiosauridae Seeley
Genus *Haplocanthosaurus* (Hatcher 1903b)

Diagnosis — Cervical vertebrae of only moderate length, pleurocoels prominent but simple, neural spines of poste-rior cervicals and anterior dorsals not divided. Dorsal

Fig. 2C. Quarry site, late summer, 1954, showing the removal of the first of 3 large plaster jackets, the 2500 lb. "Iceberg." Ed Delfs (by jacket), Joe Rhode (wearing hat) and unidentified truck driver.

centra relatively small, all containing prominent pleuro-coels; dorsal arches high with diapophyses extending upward at 45 degrees as well as outward, spines short and broad. Sacrum consisting of the usual dorso-sacral, three primary sacrals and a caudo-sacral with centra coosified, as are the sacral ribs, to form a yoke; small pleurocentral cavities in at least some of the centra; spines relatively low with a tendency toward coalescence of all, but particularly numbers one to three. Caudal centra amphicoelous, short, and without pleurocentral cavities; chevron facets very prominent and give the underside of the centrum a sculptured appearance; caudal spines slender and curved backward in the anterior region; they are of moderate height anteriorly and low further back. Distal end of scapula thin and broadly splayed; proximal plate relatively smaller than in most sauropods. Sternal plates large and subquadrangular. Proximal part of ischium relatively small, shaft straight, distal end slighty broadened but not thickened. Femur neither overly slender nor stout, the latero-medial diameter of the shaft significantly exceeding the antero-posterior one as in *Brachiosaurus*. Other possible significant generic characters are discussed below in connection with speci-

mens probably, but not certainly, belonging to *Haplocanthosaurus*.

Haplocanthosaurus priscus (Hatcher 1903b)
Haplocanthus priscus Hatcher 1903a
Haplocanthosaurus priscus (Hatcher 1903b)
Haplocanthosaurus utterbacki (Hatcher 1903c)
Holotype — CM 572 (Hatcher 1903a)
Horizon and locality — Upper Jurassic Morrison Fm., Marsh-Felch Quarry, Garden Park, Colorado
Amended specific diagnosis — Medium sized *Haplocanthosaurus* with comparatively slender femur and pelvic girdle. Distal ends of ischia narrowed, rotated inward and fused to their opposite in the midline.

Type species *Haplocanthus priscus* Hatcher 1903a

Haplocanthosaurus delfsi sp. nov.
Holotype — CMNH 10380
Horizon and locality — Upper Jurassic Morrison Fm. East bank of Four Mile Creek NW 1/4, NW 1/4, Sec. 34, T.17S., R.70W., Fremont County, Colorado (Cooper Mt. Quad.).

Fig. 3.   Dick Jones exposing a section of rib, early summer 1954.

Material — CMNH 10380 cervicals 1-4, nine posterior dorsals with ribs of the left side, five sacrals, caudals 1-14, several chevrons, shaft and distal end of left scapula, fragmentary coraeoid?, right sternal plate, proximal end of left radius, proximal end of left ulna, both ilia, left pubis, left ischium, left femur.

Diagnosis — Very large *Haplocanthosaurus* with most measurements 35-50% greater than that of the fully adult holotype of *H. priscus* (CM 572). Girdle bones and femur more robust than in *H. priscus*. Pubis in particular, much heavier distally. Distal end of ischium broader, not rotated inward and not fused to its mate. V-shaped, anterolaterally projecting laminae present on neural spines of the middle dorsals, and greater developement of median laminae on the posterior dorsal spines than in *H. priscus*.

Designation of the specimen

As mentioned in the introduction, Hatcher changed the generic name from *Haplocanthus* to *Haplocanthosaurus* because *Haplocanthus* was "essentially preoccupied" by a genus of fish named by Agassiz in 1844. Agassiz used the spelling *Haplacanthus*. A similar situation exists with the stegosaur originally named *Kentrosaurus* by Hennig (1915) but altered to *Kentrurosaurus* (Hennig 1916) because Lambe had used *Centrosaurus* for a genus of ceratopsian. Following Romer (1966), Galton (1982) has recently re-

turned to the use of *Kentrosaurus,* arguing the "two generic names cannot be considered homonyms even if it is only one letter which is different *(International Code of Zoological Nomenclature* 1961 Article 56a)." This discussion has been challenged by Anderson (1982) who argued that Hennig made the correct decision based on the rules in 1915. In the present case, *Haplocanthosaurus* is clearly the valid form, because the senior synonym *Haplocanthus* must be considered a forgotton name *(nomen oblitum)* due to lack of use (ICZN, 1961 art. 23b). The most recent edition of the Code (ICZN, 1985), however, does not use the term *nomen oblitum* and requires that the current usage be maintained while the matter is referred to the commission for a ruling (art. 23b).

Skull and mandible

No part of the skull, mandible, hyoid bones, proatlas, or any portion of the dentition has been found with any of the three partial skeletons of *Haplocanthosaurus.* The skull on the mounted skeleton is modelled. However, see comments concerning *Morosaurus agilis* below.

Vertebrae

Cervicals. The number of cervical vertebrae in *Haplocanthosaurus* is not known. In CM 572 only the last two were preserved. In CM 879 there were seven complete cervicals, an additional centrum, an arch, and a fragmentary arch. The atlas and axis are not represented. From this material Hatcher surmised that the total number of cervical vertebrae was fifteen, the same as in *Diplodocus,* the only sauropod in which the number was known with certainty at the time. Since then, a number of sauropod genera have been found to have fewer than fifteen cervicals, and indeed, von Huene (1929) revised Hatcher's figure down to thirteen. The Cleveland skeleton does not help resolve this question, but by providing the atlas and axis (Fig. 6), which are missing in the Pittsburgh material, it does add significantly to our knowledge of the animal.

Although most of the neural arch of the atlas is missing, what remains shows that it was firmly coalesced to the intercentrum as in all other adult sauropods. The odontoid is firmly united with the anterior end of the axis and extends straight forward, tapering and ending in a blunted point. The intercentrum is relatively longer than in *Apatosaurus,* but as in the atlas of the latter, well-developed articular facets for a single headed cervical rib occur on the posterior part of the lateral face. The ribs mounted on the atlas are both plaster, however, the cervical rib attached to the left side of the axis is real, and is clearly single-headed, lacking a dorsal tubercular process. The capitular end is considerably expanded and conforms well to the articular surface of the atlas. The distal end of the rib is rounded and restored in plaster. It seems likely that it was displaced from the atlas and that the axis bore a double-headed rib as is typical of sauropods.
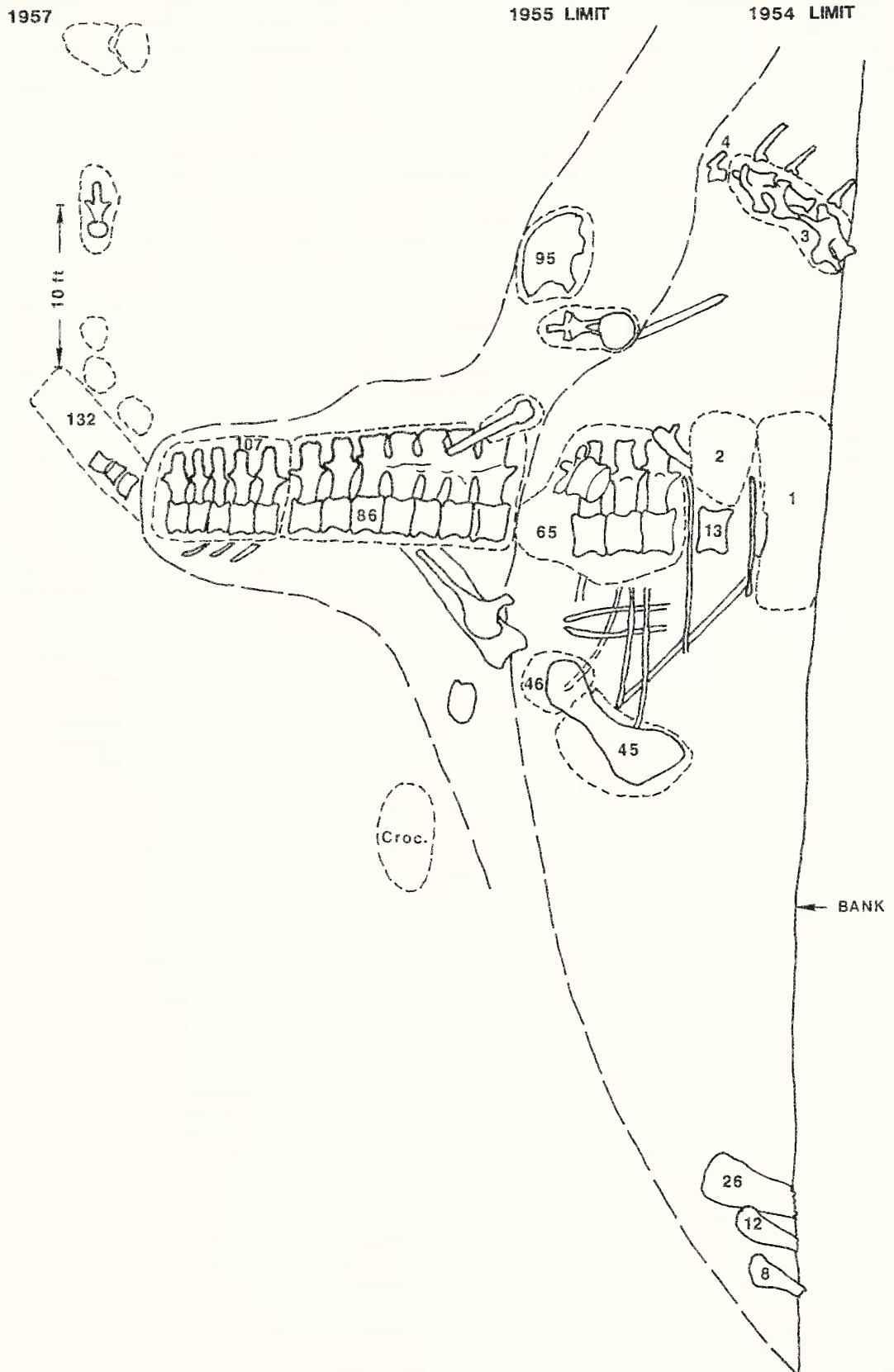
Fig. 4. Quarry map redrawn from field notes. The extent of the three summers' activities are indicated by dashed lines. Jacket no. 2, containing portions of rib and apparently the neural spine of the dorsal vertebrae in PK 13, was lost in an early flash flood. (Not to scale.)
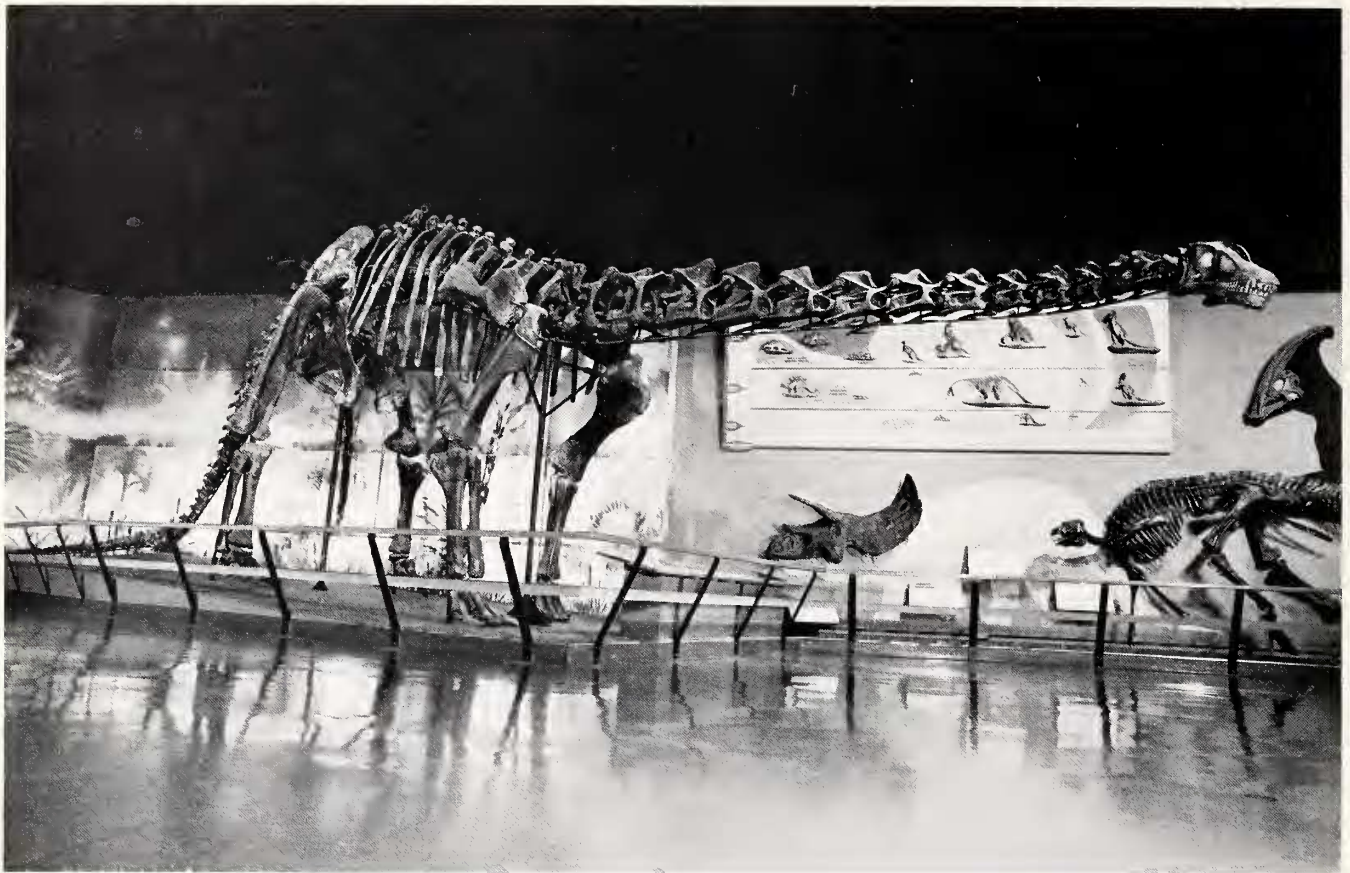
Fig. 5.   *Haplocanthosaurus delfsi,* mounted skeleton on display in Kirtland Hall, Cleveland Museum of Natural History.

The axis (Fig. 6) is complete except for the lower front part of the arch, which would have included the articulation with the neurapophysis of the atlas. A moderate depression occupies a large part of the lateral face of the centrum rather than a true pleurocoel. The anterior part of this depression is deepened into a small round cavity that penetrates the medium septum. Below and slightly anterior to this opening is a well developed, dorso-ventrally elongate, articular facet, the parapophysis. The transverse process arises on the rear of the lower part of the arch, however, the distal portions of both processes are restored.

As in other sauropod axes, the arch and spine sweep back and upward from front to rear and the postzygapophyses lie directly beneath the high point of the spine and directly above the rearmost part of the centrum.

In cervical three the lateral depression occupies about half of the side of the eentrum. The vertebra is strongly opisthocoelous and the prezygapophyses extend beyond the anterior ball of the centrum. The diapophyses lie further forward than in the axis, and both the neural spine and the postzygapophyses are higher. As the distal end of the cervical rib is not preserved, it cannot be ascertained whether or not it extends beyond the back end of the centrum.

The fourth cervical is considerably larger than the third and is also strongly opisthocoelous. The edges of the lateral depression are sharper but do not yet define a true pleurocoel. The zygapophyses resemble those of cervical three, but the postzygapophyses are placed higher. The undivided spine has assumed a triangular shape. Again nothing can be said concerning the extent of the cervical rib.

The fragment identified by Hatcher as a postzygapophysis of cervical three in CM 879 is too fragmentary to be of any comparative value. Unfortunately the centrum of cervical 4? of CM 879 has been damaged since Hatcher's day and only the rear half remains. Its lateral depression is similar to that of CMNH 10380. The arch is much distorted, but differs in no important way from that of the Cleveland specimen, so while Hatcher's identification of it as the fourth may be correct this cannot be verified with certainty.

A more significant comparison can be made between the cervicals of CMNH 10380 and those of a specimen found directly beneath a left femur associated with USNM 4275, discussed below as probably belonging to this genus. The specimen USNM 5384, consists of the braincase, proatlas, atlas, axis, and cervical 3. It was described briefly by Marsh (1889) as *Morosaurus agilis* sp. nov., and in detail

Fig. 6.   First four cervical vertebrae of *Haplocanthosaurus delfsi*, CMNH 10380. Most of the arch of the atlas and the cervical ribs are restored. Left lateral view.

by Gilmore (1907), who suggested that it might belong to *Haplocanthosaurus* since it came from the same quarry as the holotype. A direct comparison of this specimen with the Cleveland skeleton appears to bear out Gilmore's conjecture. The Washington specimen has been crushed as are most of the specimens from the Marsh-Felch quarry, but when one takes into account 1) Gilmore's observation that, "the spinous process of cervical 3 has been crushed forward somewhat from its normal position" and that 2) "the transverse process, postzygapophysial lamina and postzygapophyses are wanting," the two specimens appear quite similar. This is not only apparent in the general shapes of the first three cervicals but more specifically in the simple characters of their pleurocentral depressions. These are not crossed by laminae nor punctuated with subsidiary cavities as in many of the more advanced sauropods, and their margins lack the sharp lips characteristic of a true pleurocoel.

It will not be our intent here to discuss the skull fragment; suffice it to say that it differs significantly from that of *Camarasaurus (Morosaurus)* and the other Morrison sauropods. The presence of complete right and left halves of the proatlas in position in USNM 5384 is of great interest, since this element is rarely reported in the sauropods.

Although it seems likely that *Morosaurus agilis* is synonymous with *Haplocanthosaurus priscus,* we refrain from invoking the law of priority at this time, because of the distorted and incomplete nature of USNM 5384, and because the first three cervicals are not among the most diagnostic elements of the sauropod skeleton.

Dorsal Vertebrae. Nine dorsal vertebrae are preserved in CMNH 10380. The first six of these appear to have been in articulation, but the seventh had been displaced upward and rotated onto its side (see additional comments concerning the numerical sequence, below). The eighth dorsal was displaced further back and lay near the ilium. The ninth had been carried still further back and was found beyond the fourteenth (last preserved) caudal vertebra. As it turned out, collecting ended in 1954 with the seventh dorsal in the series (Fig. 4). Collecting resumed in 1955 with the eighth dorsal and the sacrum, but the widely displaced ninth dorsal was not recovered until 1957. Field notes indicate that the latter was displaced at least twenty feet from the articulated series. Thus, the question arises as to whether additional dorsals between the seventh and ninth may have also been displaced and lost. For a number of reasons, we believe that this is not the case, and that the series which is mounted as the nine dorsals anterior to the sacrum is correctly restored. Unlike most of the other Morrison sauropods, in *Haplocanthosaurus* the variation from one posterior dorsal to another is minor.

Using the two Pittsburgh skeletons, Hatcher determined the number of dorsal vertebrae in *Haplocanthosaurus* as fourteen. In CM 572 there were three articulated vertebral segments, the first of which he took to be the last two cervicals and first dorsal. The second segment consisting of nine dorsals, he took to be the last nine, while the third segment represented the sacrum and tail. In CM 879 the presacral vertebrae lay in approximate order, but only a series of six posterior dorsals were actually articulated. He

TABLE 1
Measurements of Cervical Vertebrae, CMNH 10380

No.	length	Centrum or Intercentrum				overall height	Height		Spread
		anterior		posterior			pre-zygap.	post-zygap.	Diapo-physes
		breadth	height	breadth	height				
1	65	66	65	63	85	e200	---	---	---
2	192	70	98	80	97	277	---	194	113
3	237	106	102	55	72	282	186	203	172
4	300	123	123	72	71	305	197	232	197

All measurements here and elsewhere in this paper are in millimeters. e - estimated

took thirteen of these to be dorsals two through fourteen; dorsal one represented in CM 572 being absent. Some years later von Huene (1929) used Hatcher's figures to reinterpret these assignments and concluded that Hatcher's dorsal one was really the penultimate cervical and that his dorsal two was actually the last cervical, thus reducing the dorsal count to twelve. Briefly stated, the reasons for the change were the occurrence of the parapophysis below the pleurocentral cavity and the fact that *Camarasaurus* had recently been shown to have twelve dorsals. The other two sauropod genera with known dorsal counts at the time of von Huene's paper were *Diplodocus* and *Apatosaurus* both of which had ten. Subsequently the Chinese genus *Euhelopus* was shown to possess fourteen, and the prosauropod *Plateosaurus* had fifteen, including the last one which is taken into the sauropod sacrum as a dorso-sacral. Thus it would not be surprising if a relatively primitive sauropod like *Haplocanthosaurus* did indeed possess fourteen dorsals. Theoretical arguments aside, the empirical evidence also favors Hatcher's interpretation. As students of the sauropods know well, the transition from cervicals to dorsals in this group is quite gradual, and the determination of where the change occurs is based on the ribs. The transition from the last cervical rib to the first thoracic rib is abrupt. In *Diplodocus* the parapophysis drops significantly on the arch of the fifth dorsal from the position seen in subsequent dorsals. In the fourth and third it is lower on the centrum in front of the pleurocentral cavity, and in dorsals one and two it lies beneath this cavity. Dorsal one resembles the last cervical more closely than it does a typical dorsal, but it bears a true thoracic rib. There is another difference: in mature sauropods the cervical ribs are invariably coalesced to their vertebrae whereas the thoracic ribs are not. In CM 879 the neural arches of most of the presacrals and sacrals are not fused to their centra, and the cervical ribs are not fused to their vertebrae, thus indicating an immature individual. In CM 572, however, all the arches are firmly fused to their centra, no trace of the line of fusion remaining. Likewise the cervical ribs on both sides of the two anteriormost vertebrae of segment one are firmly fused to their vertebrae, while the ribs of the third are free (and have been lost). Furthermore, the parapophyses lie beneath the pleurocentral cavity at the base of the centrum, which is to be expected in the first dorsal. It would appear to us that the

only possibility for reducing the number of dorsals from fourteen would be if Hatcher's dorsal two of CM 879 corresponds to his dorsal one of CM 572. This would reduce the number to thirteen, and might conceivably be attributed to individual variation, although not even von Huene suggested this possibility. While admitting that future discoveries might bear out this possibility, we believe that based on current evidence, it is more prudent to stick with Hatcher's original determination of fourteen dorsals.

What then are the locations in the series of the CMNH 10380 dorsals? It seems reasonably certain that the first six and probably the first seven occurred in serial order. The first package taken out, PK 1, was a 750 lb. block said to contain "assorted bones" (Fig. 5). A later, typed version of the field notes lists PK 1 as containing "vertebra in scrappy condition." Package no. 2, which was immediately behind PK 1, contained the neural arch of another dorsal, labelled PK 13 on the quarry diagram. Unfortunately, PK 2, plastic jacket and all, was lost in a flood early in the excavation (Fig. 7).

In the mounted skeleton, two dorsals were placed anterior to the one missing the neural arch (Fig. 8), suggesting that the first two were in PK 1. Evidence tending to confirm this is the considerable difference in the anterposterior expanse of the neural spines of the first two vertebrae. This is in contrast with the remaining dorsals, whose neural spines are essentially uniform in this respect, as are the rearmost dorsals of both CM 879 and CM 572.

The two displaced dorsals have been mounted as the two between the sacrum and the former group and they seem to fit well in this series (Fig. 9). A hyposphene-hypantrum articulation is present in the dorsals of both Carnegie specimens from the sixth to the last. These articulations are likewise present in the dorsals of CMNH 10380, save for the first and third where they are restored in plaster. The hyposphene on the first dorsal may be partially real, but the presence of a hypantrum on the second demonstrates its presence nonetheless. It would seem, therefore, that the series is correctly restored, and represents dorsals six through fourteen (dorsals four through twelve in the mount).

One apparent difference, however, is the position of the capitular articulation on the sixth dorsal, which in CMNH 10380 is at the same level as in succeeding vertebrae, but

Fig. 7. One of several flash floods that plagued the excavation. Joseph Hurley is seen standing atop a large plaster jacket. Summer 1955.

distinctly lower and greatly enlarged on the sixth dorsal of both Carnegie Museum specimens.

Detailed descriptions of the dorsals are unnecessary since Hatcher's suffice, but several points should be noted concerning the new specimen. First, all the neural arches are firmly fused to their respective centra. The centra are relatively small, as in CM 572 and CM 879, with large, sharpley defined pleurocentral cavities high up on the centra. The anterior and middle centra are strongly opisthocoelous, the posterior ones less so (Fig. 8). Indeed, the anterior ball of the last three are only slightly convex to nearly flat. The centra of dorsals 13 and 14 are noticeably shorter than the others, but number 13 has clearly received some antero-posterior flattening (crushing) so this feature may be exaggerated. The neural arches and spines are, for the most part, in accord with the Carnegie Museum specimens. The arch is high, the spine short and broad and the diapophyses are directed strongly upward as well as outward. The arches of dorsals 6 and 7, the first bones collected and those just in front of the segment of the column eroded away by the stream, have required some restoration (e.g. the left diapophysis of dorsal 6 has been restored in plaster), but they are for the most part intact. As noted above, the arch and spine of dorsal eight were lost in a flood and have been completely restored. The remaining six dorsals are essentially complete, and with the exception of the minor crushing already noted in dorsal 13, they are little distorted. Finally, J. F. Bonaparte (personal communication) has pointed out some differences in the development of the laminae of the dorsal arches; in particular, the presence of V-shaped antero-laterally projecting laminae on the neural spines of the middle dorsals and a greater
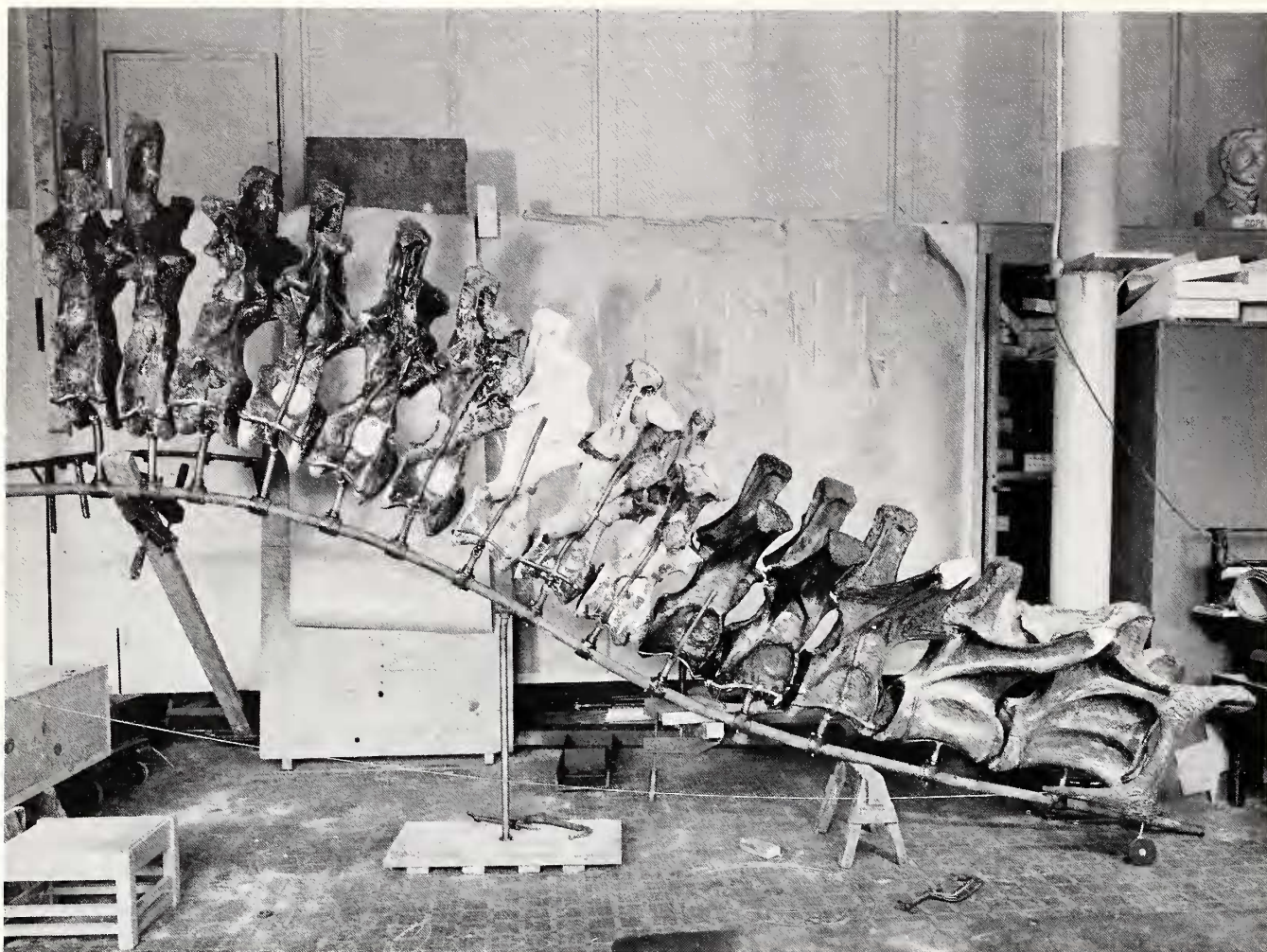
Fig. 8.   Dorsal vertebrae of CMNH 10380 (seen from right side) in the process of being mounted at the AMNH in New York. A cervical rib was later added to the second (modeled) vertebrae in the series, leaving 12 dorsal vertebrae in the mount. The last 9 dorsals are completely or in part real and are herein regarded as the posteriormost 9 dorsals of the animal (i.e. 6–14). See text for additional comments. Photo courtesy of the American Museum of Natural History.

development of the median laminae on the posterior dorsal spines of CMNH 10380. He believes these characters may indicate a new genus "related to *Haplocanthosaurus*," but different. We believe these differences indicate at most, a separate species.

Sacrum. As far as can be determined the sacrum is in almost complete agreement with that of CM 572. The dorso-sacral and caudo-sacral centra are totally fused to those of the three primary sacrals. Furthermore, the arches of all five vertebrae are firmly fused to one another and to the sacral ribs. As in CM 572 the short to moderately long spines of sacrals one through three are firmly united throughout, and those of sacrals four and five are united to midheight. In CM 572 spines four and five are free, but this is probably an individual character because in the even younger CM 879 all five spines are united. As mounted it is not possible to determine the existence of pleurocentral

cavities. As in CM 572, the spine of the dorso-sacral is strongly inclined backward and that of the caudosacral strongly inclined foreward.

Caudal Vertebrae. The first fourteen caudal vertebrae were found articulated with the sacrum. Other than appearing slightly heavier than those of CM 572 and CM 879 (a probable age character), they resemble the latter closely (Fig.10). The centra are short, amphicoelous, lack side cavities, and bear prominent chevron facets, particularly on the posterior end of the centrum. In the first two vertebrae the diapophyses (more correctly caudal ribs) bear a hint of the wing-like processes seen on the anterior caudals of the diplodocids (in contrast to those of *Camarasaurus* and *Brachiosaurus*). Further back they are simple and extend horizontally, diminishing in size from number one to fourteen (the last preserved). The prominence of the diapophyses on the fourteenth caudal suggests that they were

TABLE 2
Measurements of the Dorsal Vertebrae

No.	length	Centrum				overall height	Height	
		anterior		posterior			pre-zygap.	post-zygap.
		breadth	height	breadth	height			
6	e255	158	172	193	238	795	---	---
7	e245	172	193	190	236	875	465	---
8	230	182	215	213	248	---	---	---
9	e255	191	233	214	242	840	---	---
10	e248	211	263	237	274	913	---	---
11	e243	245	263	271	288	935	---	---
12	201	319	254	370	313	915	---	---
13	144	334	298	349	337	1040	---	---
14	170	338	278	349	293	1010	---	590

Note: These measurements were taken with some difficulty from the mounted skeleton. Minor errors may be present.

present on several succeeding vertebrae. This is in contrast to the situation in CM 572, where the diapophyses have all but disappeared on caudal thirteen. The first caudal bears a typical spine which is directed first upward and then curves around toward the back, resembling that of CM 879 closely. In CM 572, caudal one was displaced and badly crushed. When restored by the artist Sydney Prentiss, this curvature was not indicated. Behind caudal number one the spines are relatively slender, straight, and directed upward and backward.
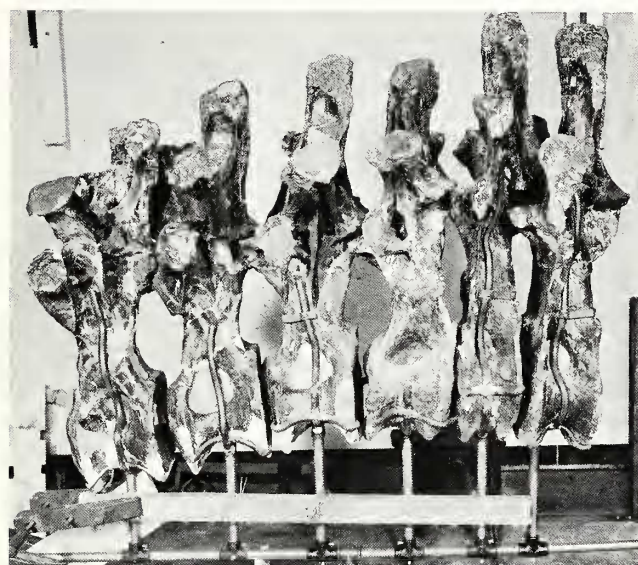

Fig. 9. Last 6 dorsal vertebrae of CMNH 10380 as seen from the left side. Photo courtesy of the American Museum of Natural History.

Ribs. In the mounted skeleton the left ribs attached to dorsals six through thirteen are at least partially bone. The other ribs have been restored in plaster. Field diagrams show that the left ribs nine, ten, and eleven were articulated

TABLE 3
Measurements of the Sacrum of CMNH 10380

Length of five centra	1090
Length of centrum of Sacral 1	202
Anterior breadth of same	301
Length of centrum of Sacral 2	234
Height of Sacral 1	1020
Height of Sacral 2	1010
Height of Sacral 3	1000
Height of Sacral 4	910
Height of Sacral 5	854
Distance between distal ends of ilia externally	640

with their respective vertebrae and that twelve was little displaced. These ribs are all characteristic of sauropod dinosaurs and do not exhibit any unusual features.

Chevrons. Several incomplete anterior chevrons were found with the tail, but were displaced above it. They appear to be relatively long and straight with the bifurcate heads relatively short. The heads resemble those of *Camarasaurus,* in having no bridge of bone above the haemal canal, and are in contrast to the situation in *Diplodocus* and *Apatosaurus,* where a transverse "crus" exists.

Sternum

One of the most important discoveries with the Cleveland specimen was that of a complete sternal plate (Fig. 11), previously unknown in *Haplocanthosaurus.* Considerable controversy has existed in the literature concerning the positioning of these sternal plates. It was partly resolved —with the discovery in *Camarasaurus* USNM 13786 and *Alamosaurus* USNM 15560—that the heavy pointed end of the plate was directed forward (Gilmore 1946). This being the case the element preserved with CMNH 10380 would be the right sternal plate. It is roughly quadrangular with the length greatly exceeding the breadth. It is very gently convex downward. The lateral and medial margins are parallel and very gently curved to bulge outward from the

TABLE 4
Measurements of Caudal Vertebrae of CMNH 10380

No.		Centrum					Height		Spread
	length	anterior		posterior		overall	pre-	post-	Diapo-
		breadth	height	breadth	height	height	zygap.	zygap.	physes
1	176	346	370	270	370	865	---	---	---
2	155	294	355	226	330	770	---	---	---
3	154	266	340	231	258	728	515	460	---
4	157	289	300	231	280	680	446	430	377
5	165	257	273	220	269	620	424	390	389
6	166	257	272	191	271	578	423	386	392
7	155	217	251	203	244	547	372	372	379
8	155	216	232	210	237	530	369	356	362
9	163	313	239	213	217	491	336	349	*306
10	163	227	204	194	201	454	348	328	---
11	162	207	192	205	193	415	305	278	278
12	163	192	182	188	187	430	279	310	223
13	174	187	175	197	164	359	279	271	e247
14	167	178	147	175	161	323	261	257	231

* = distorted

midline. The medial margin is smooth, but the lateral one is irregularly rugose for the attachment of the cartilaginous sternal ribs. The posterior margin also has indentations and trends slightly forward from the outside in. The thickened anterior margin is least straight of all. It curves forward to form a blunted point and then recedes to the median margin. The plate is relatively much longer than in any other sauropod except for *Alamosaurus* and *Opisthocoelicaudia*. If and how the sternal plate articulates with the coracoid in sauropods has not been determined. The sternal bone of CMNH 10380 more nearly resembles that of *Camarasaurus lentus* USNM 13786 than any other, but sauropod sternal plates show great variation within the same genus, so this similarity may be fortuitous. This bone does not resemble the sternal of *Camarasaurus grandis* YPM 1901. After many attempts to place the sternal plates reasonably, the AMNH preparator George Whitaker was unable to settle on an arrangement that he regarded as satisfactory, and in the end, they were not placed on the mounted skeleton.

TABLE 5
Measurements of the Sternum of CMNH 10380

Length of sternal plate	755
Breadth of same	358

Pectoral girdle

Scapula. The shaft and distal end of the left scapula are preserved in CMNH 10380. This is to be compared to the scapula of CM 879 and another left scapula-coracoid, CM 33995. The latter was miscatalogued CM 94, the number of the cotype of *Diplodocus carnegii*. It does not belong to that animal but rather to *Haplocanthosaurus*. Both scapulae of CM 94 are preserved. All the bones found in Quarry D,

Sheep Creek, Wyoming (from which it derives) are represented on an excellent quarry map, and all are accounted for. In addition, the color and preservation of CM 33995 is distinctive of the Garden Park quarry and quite unlike those of bones from the Sheep Creek quarries. Finally, the quarry map of the Garden Park quarry (Hatcher 1903c) shows a complete scapula-coracoid among the bones of CM 572. It is shaded to show that it belonged to a different genus, but it is not present elsewhere in the collections in Pittsburgh. It appears to us that this bone was somehow misplaced and very likely belongs to CM 33995. If so, Hatcher's failure to refer it to the *H. priscus* skeleton is puzzling. Perhaps he considered it a bit too large.

The incomplete Cleveland specimen shows the same widely flared distal end exhibited by CM 879 (Fig. 12). The general appearance of the bone as restored would appear a bit more massive than the latter, but this may be a matter of restoration or possibly of age. The proximal (anterior) plate is restored in plaster to resemble the "normal" sauropod scapula. *Haplocanthosaurus*, like *Cetiosaurus*, differs from the norm in having a much less developed anterior plate.

Coracoid? An incomplete girdle bone found near the sternal plate may be an incomplete coracoid. If so, it is of little diagnostic value as none of the characteristic features —the coracoid foramen, the thickened glenoid surface, etc.—is preserved. It is also possible that the element is the posterior portion of the left sternal plate. One of the borders does have a scalloped outline similar to the lateral margin of the right sternal plate. On the other hand, it would appear to be slightly wider and perhaps a little thicker than the latter.

Fore Limb

Radius and *Ulna.* All that remains of the fore limb are the proximal ends of the left ulna and radius. They were
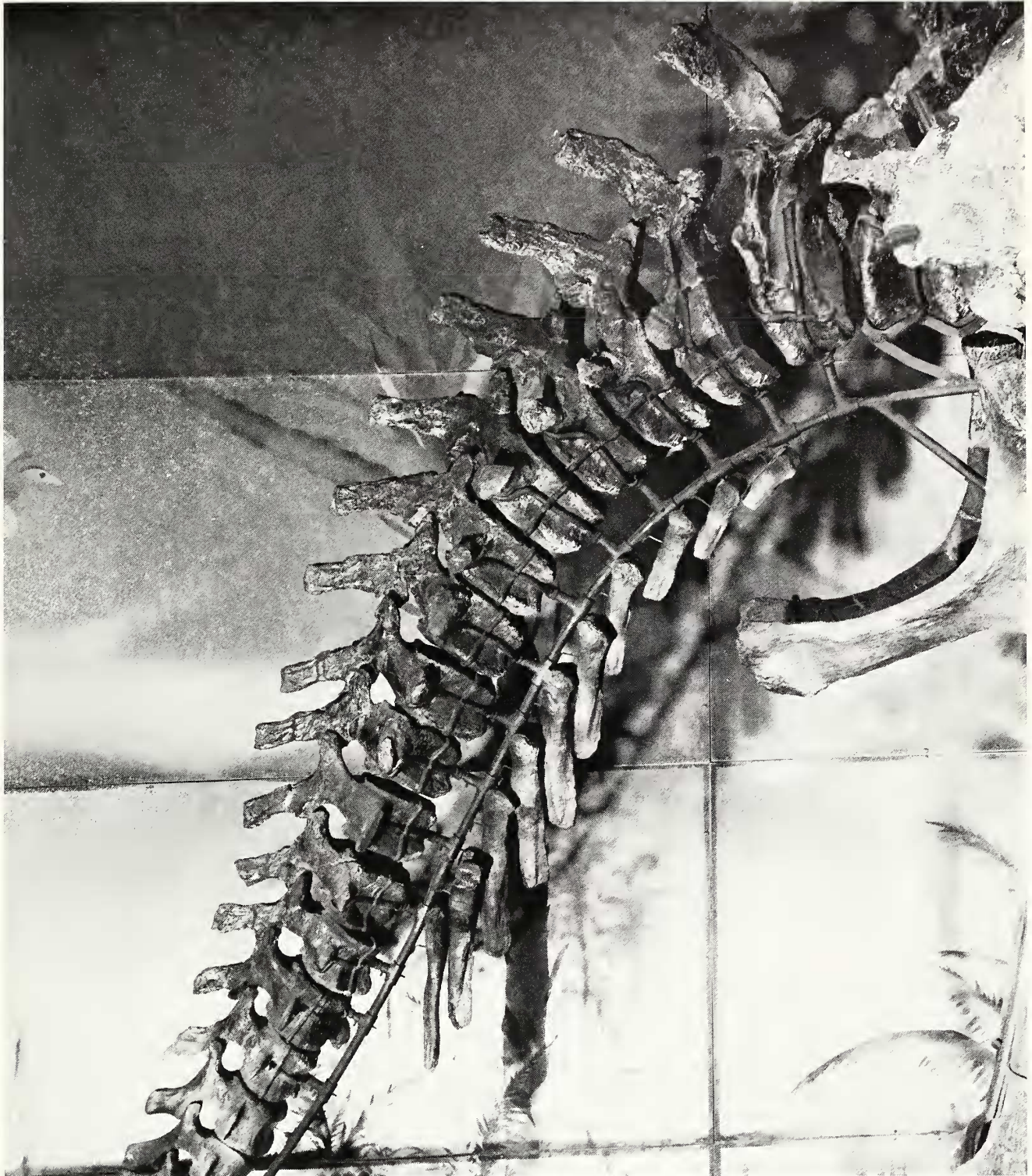
Fig. 10. Caudal vertebrae of CMNH 10380 seen from the right side. The transition from the first 14 (real) caudals to the modeled ones behind is marked by a dimunition in size of the vertical support rods beneath each vertebra.

mistaken for parts of the left tibia and fibula and were incorporated into these restored elements in the mounted skeleton. These pieces are the only fore limb bones known to belong to *Haplocanthosaurus*, but they have lost much of their value because of their fragmentary condition. The proximal end of the radius differs from that of most other
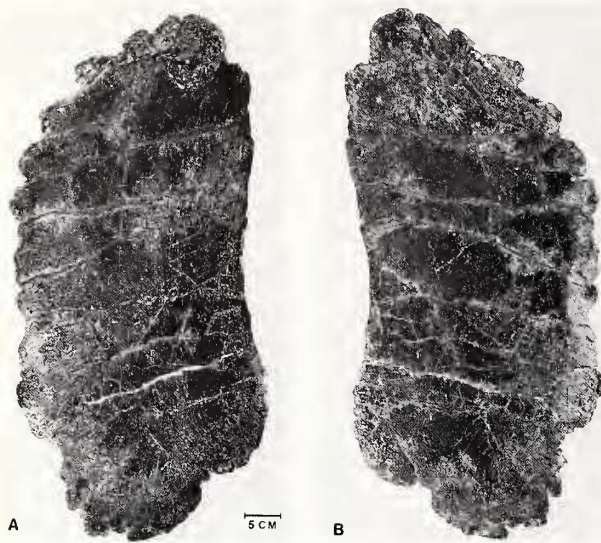
Fig. 11. Right sternal plate of *Haplocanthosaurus delfsi*. A) Ventral View B) Dorsal View.

the hook-like process that develops here in the diplodocids. As preserved the pubic foramen was open posteriorly, leaving an incomplete border for articulation with the ischium. This is almost surely the result of incomplete preservation rather than immaturity. In all known sauropod genera (certainly in all adult specimens), the foramen is ringed with bone. It has been restored to indicate the closed condition. The shaft of the pubis is stocky and the distal end is moderately expanded to meet its opposite member in the midline, although the two bones are not coalesced.

TABLE 6
Measurements of the Pectoral Girdle

	CMNH 10380	CM 879	CM 33995
Length of scapula	e1290	800	1063
Breadth, proximal	--	396	440
Breadth of shaft	--	137	154
Breadth, distal end	497	372	410
Length of coracoid ?	--	295	320
Breadth, greatest	--	350	360

sauropods in that its greatest diameter (345mm) greatly exceeds its perpendicular one. Viewed from the front, the medially-directed pointed process is prominent. Little can be said about the imperfectly preserved head of the ulna except that the anterior trough, which cradles the end of the radius, is shallow. As in other sauropods, the proximal end is V-shaped when viewed from above, but the corners of both legs of the V are incomplete, particularly that of the medial branch. This apparently led the restorers to mistake it for the cnemial crest of the tibia.

Pelvis

The bones of the pelvis and the femur of CMNH 10380 show more differences from those of the type of *H. priscus,* CM 572, than do any other of the preserved parts.

Ilia. Both ilia are present and the left one is virtually complete (Fig. 13). It is more robust than the illium of CM 572. In front of the pubic peduncle, the anterior tip of the blade is deflected outward in a manner reminiscent of the Upper Cretaceous titanosaurids, where this feature is greatly accentuated. No such deflection is observed in either the left or right ilium of CM 572. Both of the latter have been crushed but in different directions, and this may account for the apparent difference between the ilia of the two animals. The crushing is most severe in the left bone of CM 572 causing the lobe in front of the pubic peduncle to appear much longer than it was.

Pubis. The left pubis is nearly complete, and while resembling that of CM 572 it appears somewhat more robust, particularly at the distal extremity. A swelling on the upper portion of the anterior margin represents the attachment for the ambiens muscle, but there is no indication of

Ischium. The left ischium is complete and, except for the distal end, it resembles that of CM 572. The pubic articular margin is arced forward, more so than in other sauropod genera. The process for articulation with the ilium is typically long. The shaft is slender but only a little twisted. It broadens slightly at the distal end while not becoming any thicker. In CM 572 the broadening is less and the shaft is more twisted so that the two ischia meet at the distal end edge to edge as shown in Figure 14. In fact, in CM 572, the shafts of the two ischia are firmly coosified at their distal ends and for a considerable distance forward. An identical arrangement is found in USNM 4275 from the same quarry as the type and clearly referrable to *Haplocanthosaurus.* As both the ischia in CMNH 10380 and CM 572 were found articulated there can be no question that, indeed, each did belong to its assigned skeleton. Careful examination of the distal end of the left ischium of the Cleveland specimen shows that it was not coosified with that of the missing right one. Various misalignments of both the pubes and ischia of this specimen cause the distal ends of the ischia to meet in a sharp "V" rather than the shallow trough described by Hatcher (see additional comments in the final section describing the mounted skeleton). As in *Camarasaurus* and *Brachiosaurus,* none of the three specimens shows any thickening of the distal end in the perpendicular direction so typical of the diplodocids, particularly *Apatosaurus* (Fig. 15).

There is in the collection of the National Museum of Natural History an articulated sauropod hind limb of the left side with part of the foot and the associated right femur and both ischia, USNM 4275. Only the ischia bear the catalogue number USNM 4275, but the other elements clearly

Fig. 12. Left scapula-coracoid of CMNH 10380. Only the shaft and upper end of the scapula are bone.

belonged to the same individual and will henceforth be referred to by the same number. The specimen was found in the East End of the Marsh-Felch quarry whence came the types of *Haplocanthosaurus priscus* and *Diplodocus longus.* Marsh arbitrarily assigned the ischia to the *D. longus* and figured them as such (Marsh 1896). Recognizing that these ischia clearly had nothing to do with *Diplodocus,* Gilmore (1907) referred them, "to some large species of the Morosauridae," and refigured them as *Morosaurus.* They are coalesced for half their length as in CM 572 and resemble it very closely. Although bearing some resemblance to those of *Camarasaurus (Morosaurus)* these bones certainly belong to *Haplocanthosaurus.*

Hind Limb

The hind limb in CMNH 10380 is represented by the left femur only (Fig.16).

Femur. At first glance, the femur of CMNH 10380 would appear to show marked differences from that of the holotype of *H. priscus,* CM 572. Aside from its smaller size (see Table 8), the Pittsburgh specimen appears to be more slender and to have a more circular shaft, although it has suffered from latero-medial crushing; whereas the Cleveland specimen has, if anything, undergone some antero-posterior flattening.

TABLE 7
Measurements of the Pelvis

	CMNH 10380	CM 572	USNM 4275
Length of *ilium*	1315	827	---
Height of pubic peduncle	955	512	---
Breadth of acetabulum	370	---	---
Length of *pubis*	1100	693	---
Breadth, proximal end	504	---	---
Breadth, distal end	453	---	---
Length of *ischium*, distal end to pubic articulation	1000	790	800
Length of *ischium*, distal end to iliac articulation	995	---	---
Least breadth of shaft	144	---	---
Breadth, distal end	236	85	---
Length of articular surface with pubis	e440	---	---

The femur of CMNH 10380 is nearly complete although an area on the medial side of the lower half of the shaft has been restored in plaster. It is a straight heavy bone expanded at both ends, in which the latero-medial diameter considerably exceeds the antero-posterior one. The cross-section of the shaft is thus a flat oval, most closely resembling *Brachiosaurus* in this respect. The fourth trochanter is
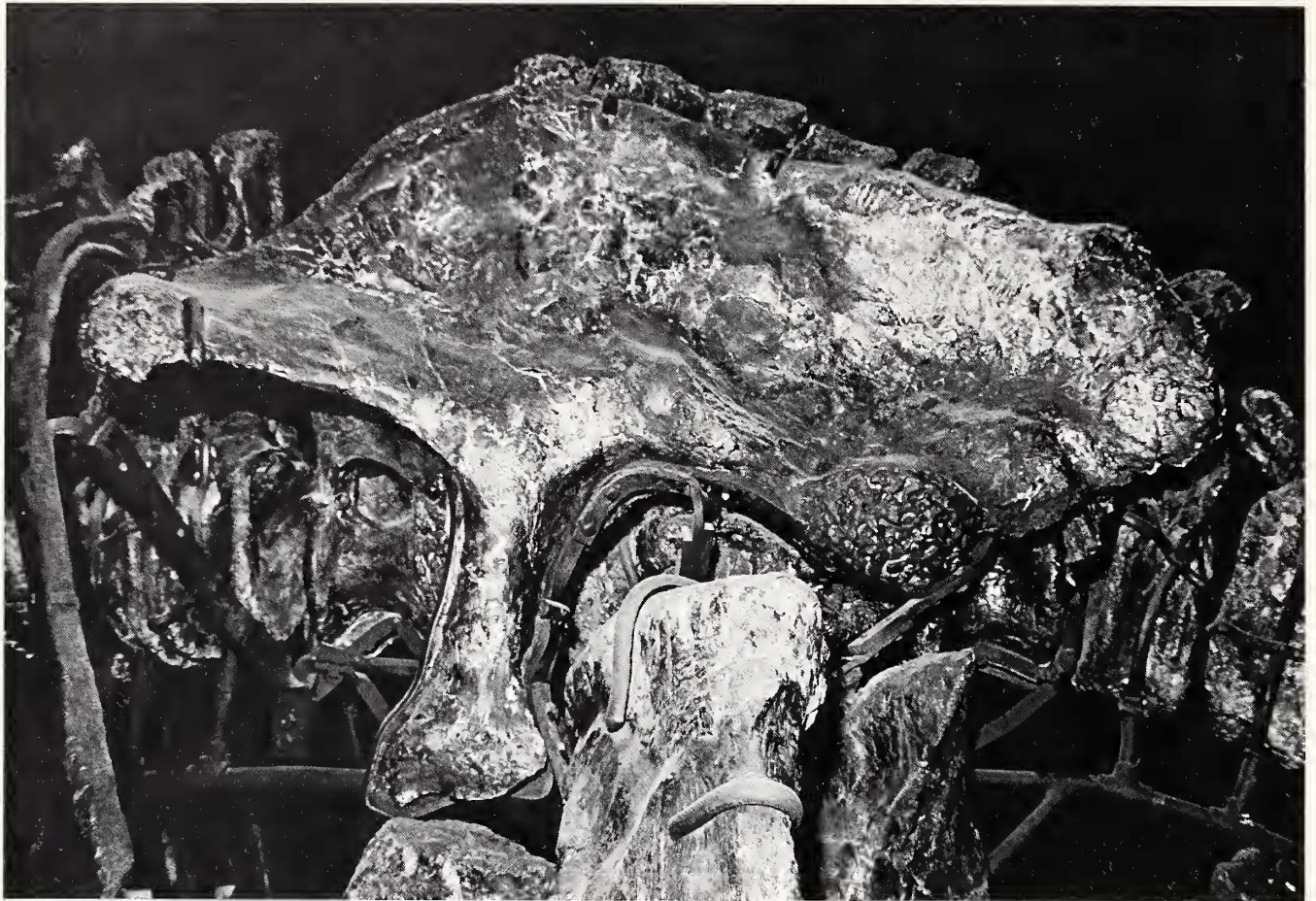
Fig. 13.   Left illium and sacrum of CMNH 10380.

located at mid-length on the postero-medial border of the shaft. The slight swelling on the upper part of the lateral-border of the shaft, which Galton (1981) has interpreted as the final vestige of the lesser trochanter, is very weak, unlike that of *Brachiosaurus*. The proximal end is broad with the head directed nearly at right angles to the shaft, and not rising much above the remnant of the greater trochanter. The horizontal projection of the head into the acetabulum is greater than in most sauropods, but that may be due to a slight deformation of the Cleveland specimen and is not observed in CM 572. The distal end is moderately expanded with the tibial condyle exceeding the fibular one in extent. The comparative measurements given below may be some-what misleading due to the crushing of CM 572 noted above.

The hind limb associated with the ischia USNM 4275 has peculiarities that preclude its reference to any of the other five Morrison sauropods: *Diplodocus, Barosaurus, Apato-saurus, Camarasaurus,* and *Brachiosaurus.* The femora are in general agreement with that of CMNH 10380 although the comparative measurements indicate a slightly more robust form. All four limb bones have been crushed; the left femur antero-posteriorly to flatten it, the right one latero-medially; although they are identical in length and were

lying across one another. The left tibia and fibula were in position at the lower end of the femur, and the ischia were also in position. The worth of USNM 4275, important in itself in providing another specimen of this rare animal, is further enhanced by providing information about the lower segment of the leg described below.

Tibia, Fibula, and *Pes.* No trace of the lower segment of the hind limb or foot have been preserved with CMNH 10380. As noted previously the proximal ends of the left radius and ulna have been incorporated into the restored left tibia and fibula of the mounted skeleton.

In USNM 4275 the left tibia, fibula, and astragalus are complete but somewhat crushed. Their most notable feature is their massiveness. The short stocky tibia is expanded at both ends, but the cnemial crest is only moderately devel-oped. The distal end is greatly expanded, more so than in any other Morrison sauropod except *Brachiosaurus.* The latero-medial diameter of the shaft greatly exceeds the antero-posterior one, but this may have been exaggerated by crushing. The astragalus is in place at the end of the tibia, but the matrix between the bones has not been removed. As presently visible, the astragalus presents no noteworthy features. The left fibula is also stocky. Its proximal end is unexpanded, the antero-posterior diameter exceeding the
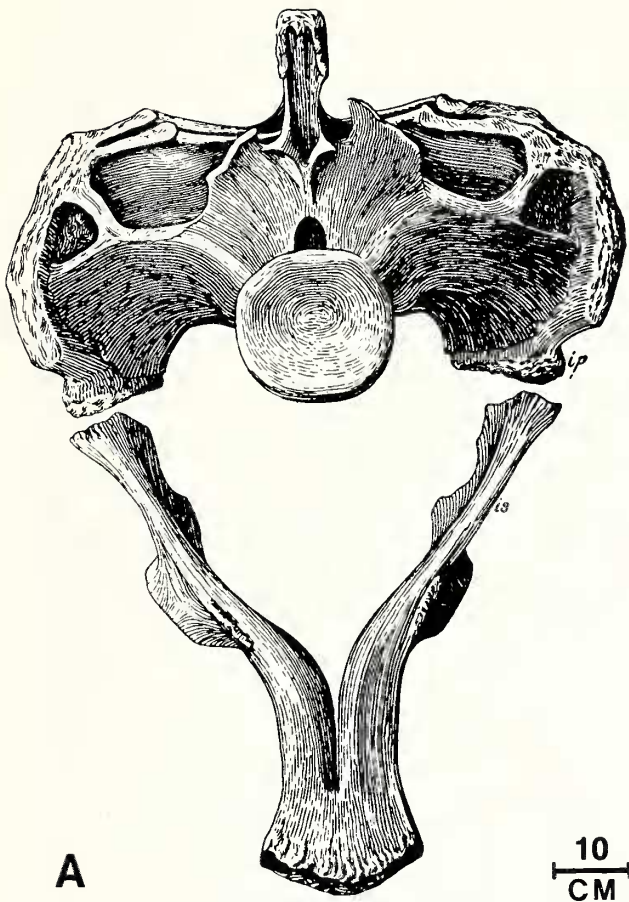
A

$\dfrac{10}{CM}$

Fig. 14. A) Pelvis of the holotype of *Haplocanthosaurus priscus* (CM 572) as seen from behind. Note the fusion of the distal ends of the ischia in the midline. (From Hatcher, 1903c).
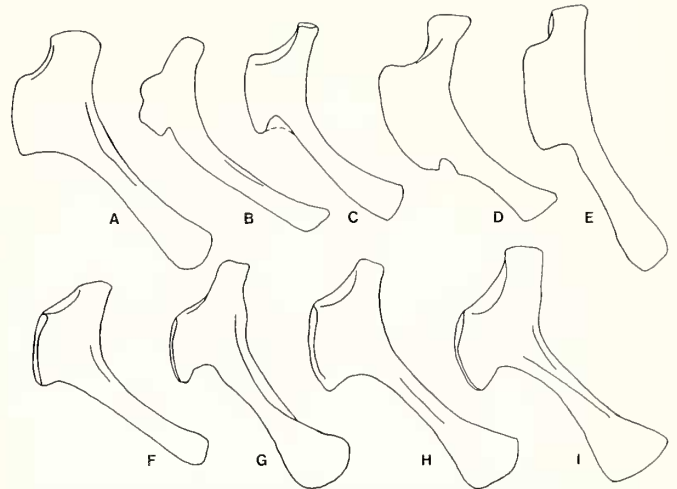

Fig. 15. Lateral Views of Left Ischia. A) *Cetiosaurus*, B) *Haplocanthosaurus priscus*, C) *H. delfsi*, D) *Titanosaurus*, E) *Brachiosaurus*, F) *Camarasaurus*, G) *Diplodocus*, H) *Dicraeosaurus*, I) *Apatosaurus*.

B

Fig. 14. B) Left ishium of *Haplocanthosaurus delfsi* CMNH 10380, Length=1000 mm.

Fig. 16. Left femur of CMNH 10380, posterior view, with Gil Stucker, Martin Cassidy and George Whitaker. Courtesy of American Museum of Natural History.

latero-medial one as usual. The lower end is slightly expanded, the two breadths being subequal. The tibial articular scar on the medial face at the proximal end is

prominent. It terminates below at a bulge on the anterior margin of the bone. In addition to the stockiness of the tibia and fibula the most striking feature of the USNM 4275 limb

is the small tibio-femoral length ratio, .52. Among the other five North American Jurassic sauropods *Brachiosaurus* is closest to this with .59, but the others are over .60. It may be added that an almost identical right tibia, fibula, and astragalus (CM 2043) were collected in the Marsh-Felch Quarry at the same time, but some little distance to the east of CM 572 and CM 879. These have been assigned to *Haplocanthosaurus* by McIntosh (1981). The tibia has a length of .627m., which is too short for CM 572, although it may belong to CM 879.

TABLE 8
Measurements of the Hind Limb

	CMNH 10380	CM 572	USNM 4275 left	USNM 4275 right
Length of femur	1745	1275	1110	1105
Breadth, proximal end	555	353	350	370
Breadth of shaft	---	207	200	195
Breadth, distal end	545	309	315	245
Thickness, tibial condyle	360	---	215	275
Thickness, fibular condyle	245	---	185	255
Least circumference of shaft	755	518	491	502
Ratio, circumference: length	.43	.41	.44	.45
Length of *tibia*			580	
Breadth, proximal end			240	
Breadth of shaft			130	
Breadth, distal end			256	
Least circumference of shaft			321	
Ratio, circumference: length			.55	
Length of *fibula*			610	
Breadth, proximal end			---	
Breadth of shaft			79	
Breadth, distal end			142	
Least circumference of shaft			218	
Ratio, circumference: length			.35	
Ratio of lengths, tibia: femur			.52	
Ratio of lengths, fibula: femur			.55	

Note: caution should be observed in using these measurements as most of the bones have suffered distortions. The lengths are probably little affected however.

The Species of Haplocanthosaurus

Hatcher referred his two partial skeletons to separate species based solely on the state of coossification of the sacral spines. *H. priscus* CM 572 is about 5% larger than *H. utterbacki* CM 879 and as noted previously has all its vertebral arches firmly coossified to their respective centra, even the suture line being obliterated. In *H. utterbacki* almost all the arches are separate from their respective centra; the scapula and coracoid are likewise not coalesced. These characters indicate that CM 879 is a younger animal than CM 572. However, in CM 572 the spines of the first three sacrals only (i.e., the dorso-sacral and primary sacrals one and two) are coossified for their entire lengths, those of

the last two sacrals (primary sacral three plus the caudo-sacral) remaining free. In the younger animal, on the other hand, the spines of sacrals one to four are fused from top to bottom and even that of number five is fused to the spine in front of it at the top and bottom. Mook (1917) studied the problem of speeiation in sauropods. In his terminology the fusion problem is one of "acceleration" in CM 879. In some unpublished notes he aeeepted Hatcher's criterion for separating the species and noted further a second supposed difference, namely, the lack of the hyposphene in dorsals eight through eleven of CM 572 and the presence in CM 879. In their present state of preservation and restoration, dorsals eight through eleven of CM 572 do indeed appear to laek a hyposphene and have been so drawn by Sydney Prentiss, but one must remember that six through fourteen of CM 572 were found tightly articulated, and the process of disarticulation, particularly of the hyposphene-hypantrum, was most difficult. After examining these specimens, we are convinced that these vertebrae originally possessed a normal hyposphene. Hatcher himself stated, "All the dorsals in this region, nos. 6–14 exhibit the hyposphene-hypantrum articulation" (Hatcher 1903c). The separation of the species must therefore stand or fall on Hatcher's original criterion regarding the union of the sacral spines. Riggs (1903) made a detailed study of the sacra of a number of individuals of *Apatosaurus (Brontosaurus)* and *Morosaurus (=Camarasaurus)* in an attempt to show that the use of the number of centra fused together in the sacrum, whether three, four, or five, was an age character rather than a generic one as employed by Marsh and others. He also discussed the union of the spines. It is now generally accepted that he made his point at least at the generic level. A great deal more study is needed before distinctive criteria can be stated for the separation of species in the dinosaurs in general and the Sauropoda in particular. This must await the full preparation and study of large population samples from quarries like those at Dinosaur National Monument, the Cleveland-Lloyd Quarry, and Como Bluff Quarry 13. There are very few such quarries, and the problems relating to preparation and study are vast. Clearly it will be some time before the necessary criteria are available. As to the problem at hand, we believe that the variations observed in the coalescence of the various elements of the sacrum of different individuals showing no other characters worthy of specific differentiation are inadequate grounds for separating *H. priscus* and *H. utterbacki*. The fact that the two skeletons were found only a few feet from one another in the same quarry at the same level in the same stratum and are so similar in all other characters adds weight to this conclusion.

The question remains as to whether CMNH 10380 belongs to *H. priscus* in light of the apparent differences in the pelvis and femur discussed above. There is also the question of the great disparity in size between the two adult animals CM 572 and CMNH 10380. There are a number of bones in the National Museum from the younger, Marsh-

Felch Quarry at Garden Park, Colorado, which probably belong to different individuals of *Haplocanthosaurus* (evidence to be presented elsewhere). All of these indicate a speeies relatively small by sauropod standards, none of them approaching in any way the size of the gigantic Cleveland skeleton. As pointed out by Mook (1917), size may indeed be significant in determining species. There are also the special characters of the laminae in the dorsal arches noted earlier. We conclude that these differences, together with the overall differences in size and robustness as well as the unfused ischia, indicate that CMNH 10380, from an older horizon, represents a distinct species, which we hereby designate *H. delfsi* after Dr. Edwin Delfs.

Relationships of Haplocanthosaurus *to other Sauropods*

Noting that the division of the Sauropoda by Marsh (1896) into six families would probably have to be reduced, Hatcher (1903c) indicated that he accepted at least the three families Atlantosauridae, Diplodocidae, and Morosauridae, and that it was to the latter family that *Haplocanthosaurus* belonged. He then compared that genus with three British sauropods and concluded that its relationship was closest to *Cetiosaurus*. The following year Riggs (1904) erected a new family for his recently discovered *Brachiosaurus* and assigned *Haplocanthosaurus* to the Brachiosauridae. The family characters he chose were 1) fore limbs longer than hind; 2) vertebral spines simple throughout; and 3) number of dorsals more than ten. Of course evidence regarding 1) was not available for *Haplocanthosaurus*. Some years later in reviewing the sauropods, von Huene (1929) referred both *Haplocanthosaurus* and *Brachiosaurus* to the Cetiosauridae, which had been established by Lydekker in 1888. Later classification schemes often place *Cetiosaurus* and *Haplocanthosaurus* together in one subfamily, the Cetiosaurinae, and *Brachiosaurus* in a second, the Brachiosaurinae, of a single family sometimes called Cetiosauridae, sometimes Brachiosauridae. We agree that *Haplocanthosaurus* should be grouped with *Cetiosaurus* in the Cetiosauridae, but believe *Brachiosaurus* and its allies have advanced sufficiently to be grouped in a separate family, the Brachiosauridae.

To compare *Haplocanthosaurus* and *Cetiosaurus* directly, we note that the skull is not known in either, at least not the complete one. The cranial fragment USNM 5384 which likely belongs to *Haplocanthosaurus* cannot be compared to *Cetiosaurus* because the corresponding fragment referred by von Huene (1906, 1932) to *Cetiosaurus* OUM 13596 does not belong to a sauropod. No teeth are known in *Haplocanthosaurus,* but the fragmentary tooth described by Phillips (1871) found with the *Cetiosaurus oxoniensis* skeleton is of the broad spatulate type. The heart-shaped teeth named by Owen (1840-45) *Cardiodon rugulosus* were considered to belong to *Cetiosaurus* by Marsh (1896)—a judgment augmented by the discovery of very similar teeth in the Middle Jurassic Argentine cetiosaurid *Amygdalodon* (Cabrera 1947). Similarities between

Haplocanthosaurus and *Cetiosaurus* suggest that the former will also be found to have teeth of this sort. Comparison of the cervicals of *Haplocanthosaurus* with those of *C. oxoniensis* is difficult because of the incomplete condition of the latter, but the partial skeleton of *Cetiosaurus* from Rutland, England, in the Leicester Museum, reported by Jones (1970) seems to agree closely with *Haplocanthosaurus* in the simplicity of the lateral cavities and the undivided neural spines. Further preparation and a detailed study of the Leicester specimen is being pursued by John Martin and when completed will allow a more critical comparison. The dorsal vertebrae of the two genera are also similar, the one complete dorsal of *C. oxoniensis* exhibiting the same high arch, short spine, and having diapophyses directed outward and upward at 45° (Fig. 17 A, B). The sacrum is unknown
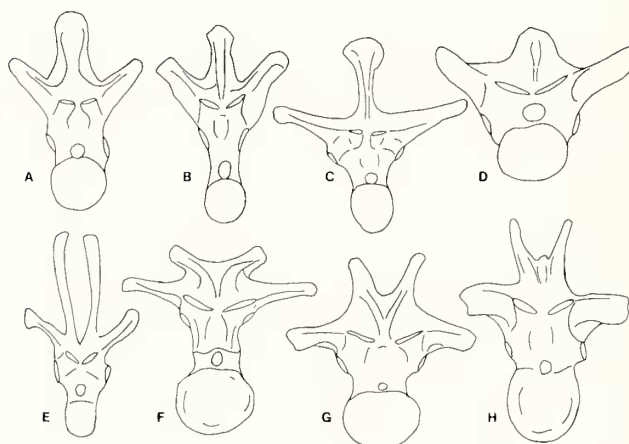

Fig. 17. Anterior Views of Antero-median Dorsal Vertebrae. A) *Cetiosaurus,* B) *Haplocanthosaurus,* C) *Brachiosaurus,* D) *Titanosaurus,* E) *Dicraeosaurus,* F) *Camarasaurus,* G) *Apatosaurus,* H) *Diplodocus.*

in *Cetiosaurus,* but the caudals are very similar to those of *Haplocanthosaurus,* one complete centrum from Buckinghamshire (OUM 13876) showing the same greatly enlarged chevron facets. The scapula of *Cetiosaurus* has a reduced proximal plate and a broadly expanded distal end; however, the expansion is not as extreme as in that of its American counterpart. Both genera have relatively broad pubes and ischia with distal ends not greatly expanded (Fig. 15 A, B). The ischia of *Cetiosaurus* from Gloucestershire, England in the Stroud Museum (Reynolds 1937) compare very favorably with those of CM 572, but less so with that of CMNH 10380 where the distal end is more broadly expanded. The femora of both animals are moderately broad, show little evidence of a lesser trochanter, and the head of each rises little above the great trochanter. Finally, the tibio-femoralratio is only .6 in *Cetiosaurus,* which is significantly greater than the .52 of the referred specimen of *Haplocanthosaurus.* Other genera of the Cetiosauridae include *Rhoetosaurus* Longman, *Amygdalodon* Cabrera, *Patagosaurus* Bonaparte, and *Shunosaurus* Dong, Zhou,

and Zhang. Preliminary notices relating to the latter two genera (Bonaparte 1979 and Dong, Zhou, and Zhang 1983) suggest more primitive forms but a full comparison must await more detailed descriptions of the vertebrae in those forms.

Comparison of *Haplocanthosaurus* with other Morrison genera shows that it agrees with *Brachiosaurus* in the undivided presacral spines (Fig. 17 B, C), but differs in having shorter cervicals with less complicated pleurocentral cavities, dorsals with smaller centra, shorter spines in the anterior region, and differently directed diapophyses. The ilium is lower in *Haplocanthosaurus*. With the diplodocids *Diplodocus, Apatosaurus,* and *Barosaurus* the contrast is very great. These taxa have presacrals with deeply cleft spines in the shoulder region (Fig. 17 G, H), fewer dorsals with lower arches, much higher spines, particularly in the rear, and diapophyses directed horizontally. Their sacra have much higher spines with the dorso-sacral spine not coalesced with primary sacral 1. Their caudal vertebrae contain pleurocentral cavities anteriorly, have far less prominent chevron facets, and these vertebrae are much more numerous and more elongate in the median and posterior regions, resulting in a vastly longer tail. The two heads of the anterior chevrons bridge across in the diplodocids but not in *Haplocanthosaurus,* and in the former the median and posterior chevrons exhibit the peculiar fore and aft expansion which reaches its extreme in *Diplodocus*; those in *Haplocanthosaurus* are simple throughout. The scapulae are quite different in the diplodocids and the distal end of the ischium is expanded greatly both in breadth and thickness (Fig. 15 G, H, I); finally the tibio-femoral ratio is well over .60.

The comparison with *Camarasaurus* is somewhat closer but here again the divided presacral spines in the latter (Fig. 17 F) are in sharp contrast. Its cervicals have more complicated pleurocentral cavities than those of *Haplocanthosaurus*; it has two fewer dorsals, 12 instead of 14, its dorsal centra are larger; the arches are somewhat lower and the diapophyses are directed outward; however the neural spines of the posterior dorsals are similar. The caudals in the two genera resemble one another, but the chevron facets are much less developed in *Camarasaurus,* and the posterior caudals are noticeably shorter in *Haplocanthosaurus* than in the latter. The chevrons themselves are quite similar, with no transverse bridge above the haemal canal and no diplodocoid fore and aft expansion. Both genera have scapulae with expanded distal ends, and both have ischia with distal ends little expanded (Fig. 15) and meeting one another edge to edge. The tibio-femoral ratio in *Camarasaurus* is a bit larger than .60; in *Haplocanthosaurus* it is apparently smaller.

The Mounted Skeleton

As restored, the skeleton is fully seventy feet long, a large sauropod (Williams 1982). All preserved elements of CMNH 10380 have been incorporated into the mounted

skeleton except the sternal plate, the supposed coracoid, and a few chevrons (Figs. 18, 5). The missing portions have been modelled or cast from specimens in the American Museum of Natural History in New York. The skull and mandible have been modelled in generalized sauropod fashion. The neck has been restored to contain fourteen cervicals of which nos. one through four are bone whereas the other ten are modelled from the Pittsburgh skeletons. Twelve dorsals have been assigned to the thorax, the first three modelled from Pittsburgh specimens and the last nine real. Left thoracic ribs four through eleven as *mounted* are, at least in part, real. The others have been restored in
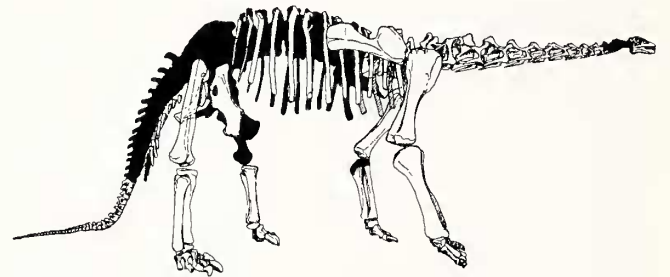

Fig. 18.   Diagram of the mounted skeleton. The shaded parts are bone.

plaster. The sacrum and first fourteen caudals are real. These are followed by several modelled vertebrae and the tail is completed with casts of an articulated series of thiry-nine caudals of *Camarasaurus* AMNH 825. The first two chevrons are real, all others restored. The left scapula, excepting the proximal plate, is bone. The right one is modelled after it and both coracoids are restored. The fore limbs and feet have been completely restored from specimens in the American Museum, based largely on *Apatosaurus*. The complete left pelvis and right ilium as well as the sacrum are real, the right pubis and ischium having been modelled from their counterparts. The left femur is real and the right one modelled from it. The tibiae, fibulae and pedes have been modelled, the (real) heads of the left ulna and radius having been incorrectly incorporated into the left tibia and fibula.

For the most part the pose of this skeleton follows the pattern of traditional sauropod mounts. The placing of the scapula was the subject of considerable debate among sauropod scholars until Gilmore's (1925) paper on *Camarasaurus* CM 11338, where the scapula was found articulated and in position for the first time. In the present mount the scapula is placed somewhat higher on the rib cage, and its orientation more horizontal than in CM 11338. Unlike many sauropod mounts the restored fore and hind feet are constructed with the properly reduced carpus and tarsus and the single claw on digit I of the manus. The only possible criticism with the manus is that the five metacarpals are mounted side by side instead of in circular fashion where the first and fifth almost meet (Gilmore 1936). In addition,

Gilmore (1932) has shown that in *Diplodocus,* and probably the other sauropods as well, the tail proceeds straight out from the sacrum for a considerable distance before it begins to descend. As mounted in this specimen, it begins to descend almost at once and continues to do so sharply. One final criticism concerns the misorientation of the pubes and the ischia. As mounted, the medial borders of the pubes are directed caudally and do not meet ventrally in the midline. This causes them to appear much broader in side view than would normally be the case and also causes the ischia to meet in a sharp "V" rather than a shallow, nearly horizontal trough. In addition, the acetabular borders of the pubes are not in line with those of the ischia, resulting in an open acetabulum which appears much larger than it was in life. This skeleton is one of only two sauropod skeletons to be mounted in the United States in the last twenty-five years, the other being the *Diplodocus* in the Houston Museum of Natural Science.

Acknowledgments

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